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Applicant: RAEDER

Docket: AMDA.316PA

Title: POLISHING UNIFORMITY VIA PAD CONDITIONING

CERTIFICATE UNDER 37 CFR 1.10
Express Mail' mailing label number: EL449833045US
Date of Deposit: August 26, 1999
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By: Lynda Jaskowiak
Name: Lynda K. Jaskowiak

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Sir:

We are transmitting herewith the attached:

- ☒ Transmittal sheet containing Certificate under 37 CFR 1.10.
- ☒ Patent Application: Pages Numbered 1-15; 16 claims; Abstract 1 pgs.
- ☒ 3 sheets of informal drawings
- ☒ An unexecuted Declaration
- ☐ Assignment of the invention to Advanced Micro Devices, Inc
- ☒ PLEASE DEFER FILING FEE
- ☒ 2 Return postcards

The fees are calculated as follows:
Basic Filing Fee = $760.00
Fee for total number of claims in excess of 20 = $18 * (16 - 20) = $0
Fee for total number of independent claims in excess of 3 = $78 * (3 – 3) = $0
Total fee due = $760.00

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POLISHING UNIFORMITY VIA PAD CONDITIONING

Field of the Invention

The present device relates generally to semiconductor devices and their fabrication and, more particularly, to chemical-mechanical polishing (CMP) tools for manufacturing and analyzing semiconductor devices.

Background of the invention

The electronics industry continues to rely upon advances in semiconductor manufacturing technology to realize higher-functioning devices while improving reliability and cost. For many applications, the manufacture of such devices is complex, and maintaining cost-effective manufacturing processes while concurrently maintaining or improving product quality is difficult to accomplish. As the requirements for device performance and cost become more demanding, realizing a successful manufacturing process becomes more difficult.

The increased complexity of semiconductor devices has lead to certain disadvantageous developments including uneven device surfaces, which become more prominent as additional levels are added to multilevel-interconnection schemes and circuit features are scaled to submicron dimensions. Typically, each level within the device is patterned, resulting in a surface with varied step-heights where metal forming the pattern remains on the surface.

Planarization is a term describing the surface geometry of a semiconductor device. Complete planarization occurs when the surface of the dielectric is flat, as in a plane. No planarization occurs when the surface of the dielectric directly models the surface of the metal pattern in the layer underneath. The degree of planarization refers to the degree to which the varied surface geometry can be planarized, or smoothed out into a planar surface. Varied surface geometry is often undesirable. Therefore, as additional layers are formed within devices, the required degree of planarization increases.

A commonly-used planarization process in semiconductor device manufacturing is chemical-mechanical polishing, or CMP. CMP is useful in the planarization of silicon wafers and of VLSI circuits between different manufacturing processes. CMP is a popular planarization method, due in part to its usefulness in the global planarization of semiconductor devices. Traditional planarization processes are restricted to effecting local planarity or topographical variation on a small scale, whereas CMP is often useful on a global scale greater than about ten microns, depending upon the CMP tool being used.

A CMP tool commonly includes a table for securing a wafer-polishing pad with a semiconductor wafer in a wafer holder arranged opposite the wafer-polishing pad. Typically, the wafer is located face-down on the polishing pad, and both the polishing pad and the wafer holder rotate. A slurry, typically including SiO_2 particles, is applied using a wand feeding to the wafer holder and pad. The rate of removal of material from the wafer is a combination of chemical and mechanical rates. The mechanical removal

rate is roughly proportional to the pressure and the relative velocity of the wafer. The chemical removal rate is a function of the size of the slurry particles and the slurry solution pH.

In addition to the use of slurry in the CMP process, a conditioner is typically used for conditioning the polishing pad. The conditioner aids in the CMP polishing process and contributes to the longevity of the pad.

A problem arises in connection with CMP processing when the rotating wafer carrier is in a position, relative to the rotating pad, that is considered center-offset. For example, the center-offset condition may include center-fast or center-slow conditions. The wafer carrier is in a position that is center-fast relative to the rotating pad when the center of the wafer is polished at a higher rate than the outer regions of the wafer. The wafer carrier is in a position that is center-slow relative to the rotating pad when the center of the wafer is polished at a lower rate than the outer regions of the wafer. The disparity in polishing rate of a wafer is attributable to non-uniform conditions. For example, the polish rate increases with increased pressure, increased slurry, or increased heat. When the wafer carrier is in a position relative to the rotating pad that results in higher pressure, higher heat, or increased slurry at the center of the wafer, the polish rate near the center increases relative to the polish rate near the edge.

In the past, these center-fast and center-slow conditions have been addressed by monitoring a set of wafers after each CMP run. For example, in connection with a CMP tool adapted to polish five wafers simultaneously, a run of five wafers would be polished and then inspected to determine whether they were experiencing a center-fast

or a center-slow state. Upon detecting a center-fast or a center-slow state, the oscillation amplitude was adjusted to compensate.

The consequences of center-fast or center-slow conditions can be severely disadvantageous. These conditions can result in damage to the pad and/or wafers processed using the pad; such damage includes, for example: long arc type scratches and shallow micro-scratches, die thickness variation, and the die containing residual slurry particles. Such damage can result in a wafer yield lost. Moreover, with the material and labor cost of each pad being in the hundreds of dollars, excessive occurrences of pad replacements can be a significant detriment.

Summary of the Invention

The present invention involves methods and arrangements directed to improving the CMP process, the improvements including but not limited to an expeditious CMP process, reduced maintenance to the CMP tool, enhanced pad wear, and increased wafer yield. The present invention is exemplified in a number of implementations and applications, some of which are summarized below.

According to an example embodiment, the present invention is directed to a method for chemical-mechanical polishing a wafer. A CMP arrangement having a polishing table and a wafer carrier adapted to carry a wafer relative to the center of the polishing table is used to polish the wafer. The pad is conditioned as a function of determining that the wafer is being polished in the center-offset manner. By using this method, the negative effects associated with center-offset polishing are diminished.

According to another example embodiment, the present invention includes a CMP polishing arrangement having a polishing pad, a wafer carrier, and a conditioning device. The wafer carrier is arranged to carry a wafer, rotate, and hold the wafer face-down on a polishing pad arranged to rotate and polish the wafer. A detection arrangement is adapted to detect whether the wafer is being polished in a center-offset manner. The conditioning device is arranged to condition the pad in response to the detection arrangement.

The above summary of the present invention is not necessarily intended to describe each illustrated embodiment or every implementation of the present invention. The figures and detailed description which follow more particularly exemplify these embodiments.

Brief Description of the Drawings

The invention may be more completely understood in consideration of the following detailed description in connection with the accompanying drawings, in which:

FIG. 1 shows a top view of an arrangement for a CMP process for polishing a semiconductor wafer, according to an example embodiment of the present invention;

FIG. 2 shows a cut-away side view of an arrangement for a CMP process for polishing a semiconductor wafer, according to another example embodiment of the present invention; and

FIG. 3 is a flow chart for a method for polishing a semiconductor wafer, according to another example embodiment of the present invention.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not necessarily to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

Detailed Description

The present invention is directed toward a new method for chemical-mechanical polishing (CMP) that improves the ability to obtain a uniform polish-rate of semiconductor wafers, longer life of the polishing pads used in the chemical-mechanical polishing process, faster throughput of semiconductor wafers, and reduced defects. According to an example embodiment of the present invention, a semiconductor wafer is arranged in a wafer carrier of a CMP apparatus having, in addition to the wafer carrier, a polishing table including a pad and a conditioning device, such as a conditioning wheel. The semiconductor wafer is polished and it is determined whether the polishing is proceeding in a center-offset manner such as center-fast or center-slow. For instance, one method for detecting whether the wafer is being polished in a center-offset manner is to remove the wafer from the carrier and measure the thickness across the wafer using a device such as a pair of calipers. The conditioning device is arranged over the pad and relative to the center of the polishing table as a function of whether the wafer is being polished in a center-offset manner and the pad is conditioned. In this manner, negative aspects of center-fast or center-slow polishing are addressed.

FIG. 1 shows a top view and FIG. 2 shows a side view of a CMP arrangement 100, according to another example embodiment of the present invention. The CMP arrangement includes a polishing table 210 having a polishing pad 140. The polishing table 210 is capable of rotation, such as shown by directional arrow 141. A wafer carrier 130 is arranged over the pad and adapted to carry a semiconductor wafer 135 and bring it in contact with the pad 140 for polishing. Although FIG. 1 shows the wafer

carrier 130 located directly over the pad 140, the wafer carrier 130 may be located with only a portion of the carrier 130 over the pad 140 in order to enhance the application of the present invention. The wafer carrier is further arranged to rotate, such as shown by directional arrow 131. Conditioning wheel 110 is arranged over the pad 140 and used to condition the pad, responsive to detecting center-offset polishing. Supply 120 is used to supply conditioning materials such as water or de-ionized water to the pad 140.

In another example implementation of the present invention, conditioning wheel 110 is further arranged relative to the center of the polishing table as a function of the detection of a center-fast condition, a center-slow condition, or the detection of neither a center-fast nor a center-slow condition. For example, although FIG. 1 shows the conditioning wheel arranged generally over the pad, the wheel may be arranged closer to the center, or closer to the edge of the pad 140. In addition, although shown by way of illustration in FIG. 1 as a wheel, the conditioning wheel 110 may include other types of pad conditioning devices.

FIG. 3 shows a flow diagram for a CMP method for addressing center-fast and center-slow polishing, according to another example embodiment of the present invention. The CMP method includes the use of a CMP apparatus having a table, a polishing pad, a wafer carrier and a conditioning device. A wafer is arranged in the wafer carrier at block 310, brought in contact with the pad and polished at block 320. If it is determined that the wafer is being polished in a center-fast manner at block 330, the conditioning device is arranged over the pad at block 340 and the pad is conditioned to correct center-fast polishing at block 350. If the wafer is not being polished in a center-

fast manner at block 330, it is determined whether the wafer is being polished in a center-slow manner at block 360. If the wafer is being polished in a center-slow manner, the conditioning device is arranged over the pad at block 370 and the pad is conditioned to correct center-slow polishing at block 380. If the wafer is not being polished in a center-slow manner, the polishing process is continued at block 390.

In a more particular example embodiment of the present invention, the conditioning device is arranged relative to the center of the polishing table in order to reduce the thickness of the polishing pad. When a particular portion of the polishing pad is thicker than the rest of the pad, that portion places greater pressure upon a wafer being polished, increasing the polish rate in that portion. By reducing the thickness, the polish rate is reduced at the thinned portion of the pad. Using this embodiment in connection with the discovery of a center-fast or a center-slow polishing condition, the pad can be thinned in the region of the pad that is polishing faster. In doing so, the pressure on the wafer from that region is reduced, and the polish rate decreases due to the reduction in pressure.

For example, FIG. 2 shows a pad that has been thinned near the edge. The thickness A at the center of the pad is greater than the thickness B near the edge of the pad. When a wafer is held against the pad having the edge thinned, the center of the wafer can be held at a location of the pad having greater thickness than the edge. Due to the greater thickness near the center, the wafer is polished center-fast. Alternatively, the center of the pad could be thinned resulting in the edge having a greater thickness

relative to the center thickness prior to thinning and enhancing center-slow polishing. In another alternative, various portions of the pad could be thinned.

While the present invention has been described with reference to several particular example embodiments, those skilled in the art will recognize that many changes may be made thereto. Fox example, many features of the above embodiments are combinable in a single conditioner arrangement and/or conditioning process. Such changes do not depart from the spirit and scope of the present invention, which is set forth in the following claims.

What is claimed is:

1. A method for chemical-mechanical polishing a wafer using a CMP apparatus having a polishing table including a polishing pad and a wafer carrier adapted to carry a wafer relative to the center of the polishing table, the method comprising:

using the polishing pad and polishing the wafer at a position relative to the center;

determining that the wafer is being polished in a center-offset manner; and

conditioning the pad as a function of the wafer being polished in the center-offset manner.

2. A method for chemical-mechanical polishing, according to claim 1, wherein the center-offset manner includes at least one of: a center-fast or center-slow manner, and further including inspecting a wafer during the polishing process.

3. A method for chemical-mechanical polishing, according to claim 1, wherein determining that the wafer is being polished in a center-offset manner includes removing the wafer from the carrier and manually inspecting a wafer.

4. A method for chemical-mechanical polishing, according to claim 1, wherein the wafer is being polished in a center-fast manner, and further including arranging a conditioning wheel over the pad and relative to the center of the polishing table.

5. A method for chemical-mechanical polishing, according to claim 4, wherein arranging the conditioning wheel comprises thinning the center of the pad.

6. A method for chemical-mechanical polishing, according to claim 1, wherein the wafer is being polished in a center-slow manner, and further including arranging a conditioning wheel over the pad and relative to the center of the polishing table.

7. A method for chemical-mechanical polishing, according to claim 6, wherein arranging the conditioning wheel comprises thinning the edge of the pad.

8. A method for chemical-mechanical polishing, according to claim 1, wherein conditioning the pad comprises altering the thickness of the pad in at least one location.

9. A method for chemical-mechanical polishing, according to claim 8, wherein altering the thickness of the pad comprises thinning the pad in at least one location where the pad is thick relative to the rest of the pad.

10. A method for chemical-mechanical polishing, according to claim 8, wherein altering the thickness of the pad comprises applying increased pressure to a portion of the pad with the wheel.

11. An arrangement for chemical-mechanical polishing a wafer, the arrangement comprising:

means for polishing a wafer;

means for holding a wafer face-down on the means for polishing;

means for determining whether the wafer is polishing in a center-offset manner; and

means for conditioning the pad responsive to the means for determining whether the wafer is polishing in a center-offset manner.

12. An arrangement for chemical-mechanical polishing, the arrangement comprising:

a polishing pad arranged to rotate;

a wafer carrier arranged to carry a wafer, rotate, and hold the wafer face-down on the polishing pad;

a detection arrangement adapted to detect whether the wafer is polishing in a center-offset manner.

a conditioning device arranged to condition the pad, responsive to the detection arrangement.

13. An arrangement for chemical-mechanical polishing, according to claim 12, wherein the conditioning wheel is further arranged relative to the center of the polishing

table as a function of whether the wafer is polishing in a center-fast or center-slow manner.

14. An arrangement for chemical-mechanical polishing, according to claim 12, further comprising a supply arranged to supply conditioning material to the polishing pad.

15. An arrangement for chemical-mechanical polishing, according to claim 14, wherein the conditioning material is supplied responsive to the detection arrangement.

16. An arrangement for chemical-mechanical polishing, according to claim 15, wherein the conditioning material comprises water.

Abstract

According to an example embodiment, the present invention is directed to a CMP apparatus having a polishing table, a wafer carrier adapted to carry a wafer on a pad, and a conditioning wheel. If the pad is being polished in a center-fast or center-slow manner, the conditioning wheel is used to condition the pad and to improve the center-fast or center-slow condition. Benefits of using this embodiment include improved wafer quality, improved pad life, a reduction in defective wafers, and faster production.

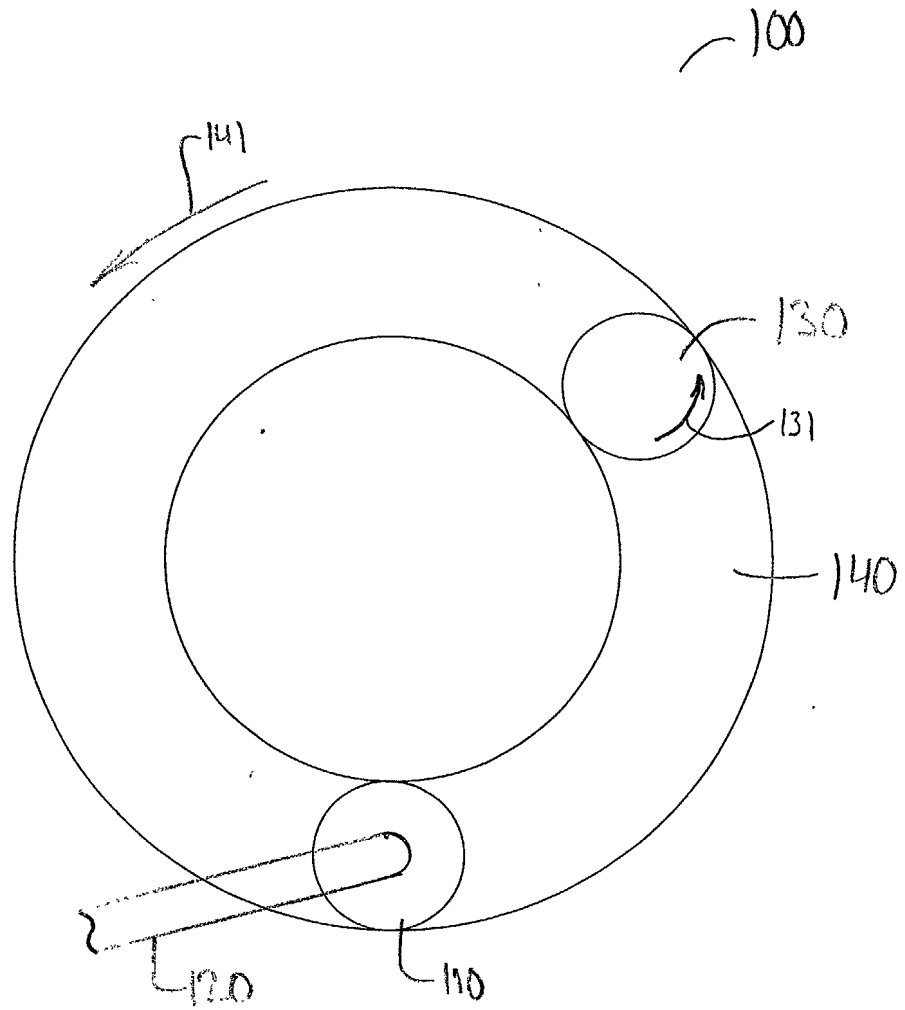

Fig. 1

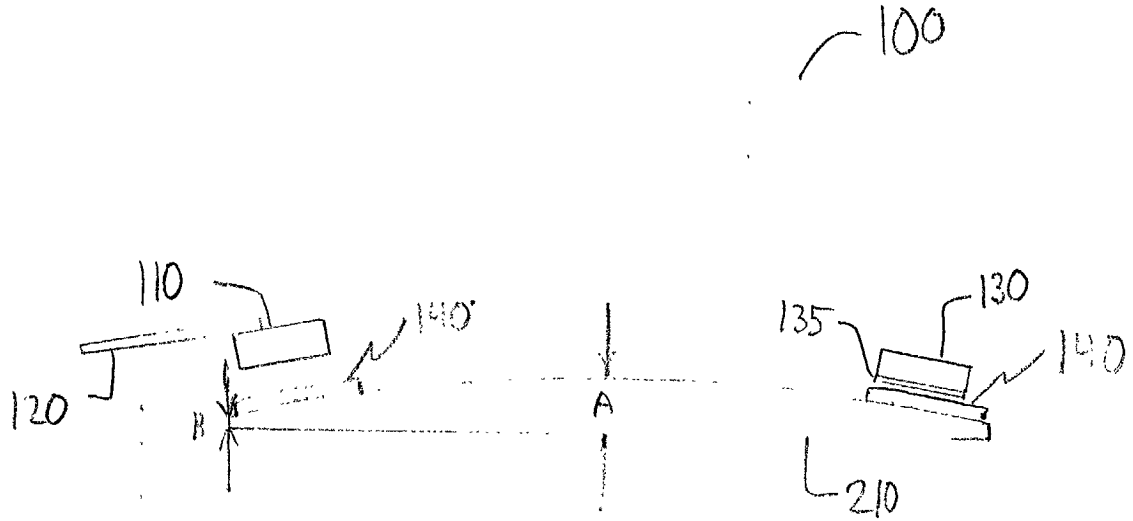

Fig 2

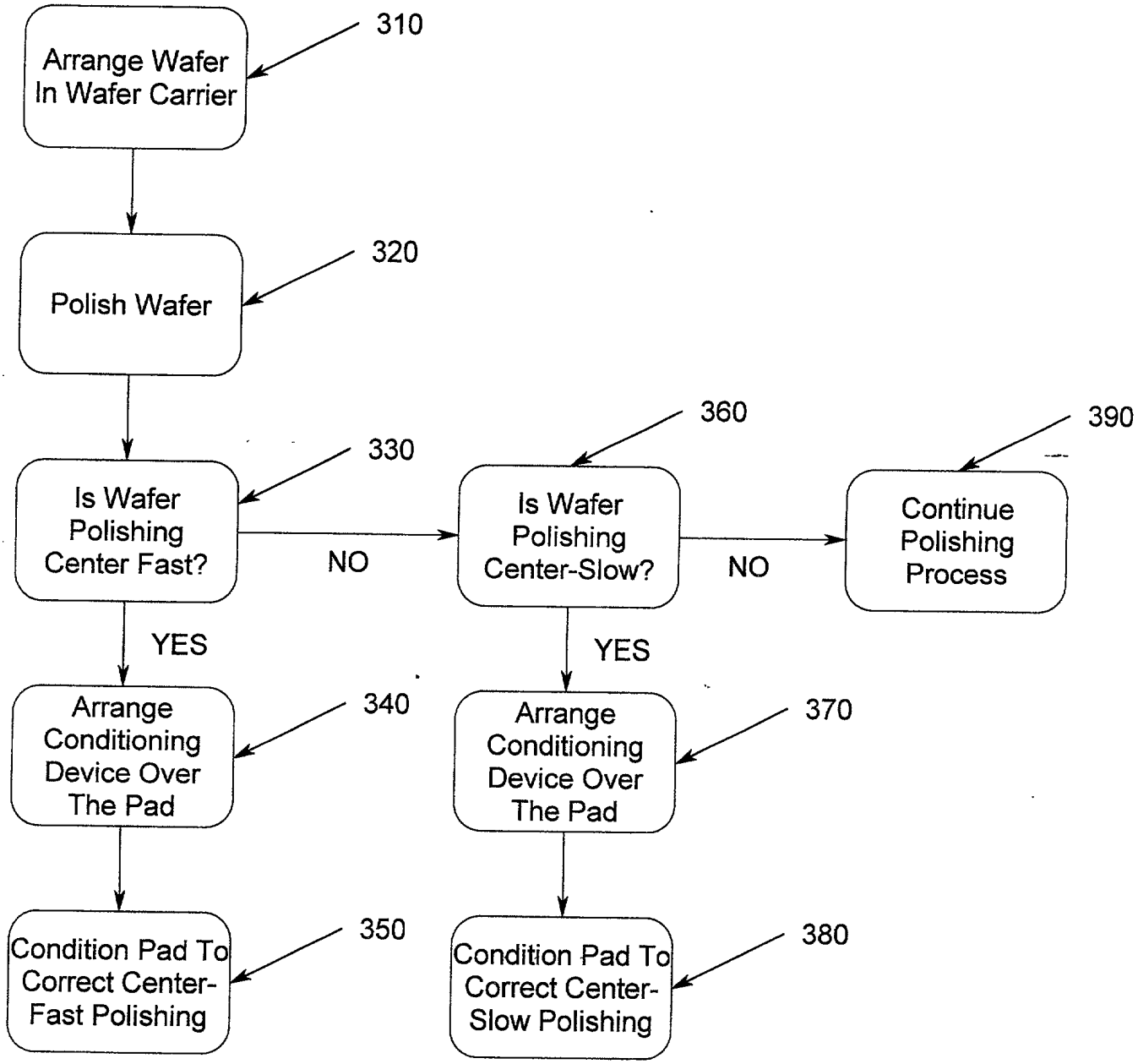
Arrange Wafer In Wafer Carrier
310
Polish Wafer
320
Is Wafer Polishing Center Fast?
330
NO
Is Wafer Polishing Center-Slow?
360
NO
Continue Polishing Process
390
YES
YES
Arrange Conditioning Device Over The Pad
340
Arrange Conditioning Device Over The Pad
370
Condition Pad To Correct Center-Fast Polishing
350
Condition Pad To Correct Center-Slow Polishing
380

Fig. 3

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United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **POLISHING UNIFORMITY VIA PAD CONDITIONING.**

The specification of which
a. ☐ is attached hereto
b. ☒ is entitled **POLISHING UNIFORMITY VIA PAD CONDITIONING,** having attorney docket number **AMDA.316PA.**
c. ☐ was filed on as application serial no. and was amended on (if applicable) (in the case of a PCT-filed application) described and claimed in international no. filed and as amended on (if any), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

a. ☒ no such applications have been filed.
b. ☐ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**
ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (Day, Month, Year)

I hereby appoint the following attorney(s) and/or patent agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

Crawford, Robert J.	Reg. No. 32,122	Maunu, LeRoy D.	Reg. No. 35,274
Drake, Paul S.	Reg. No. 33,491	Miller, Louise K.	Reg. No. 36,609
Tortolano, J. Vincent	Reg. No. 31,433	Pitruzella, Vincenzo D.	Reg. No. 28,656
Apperley, Elizabeth A.	Reg. No. 36,428	Roddy, Richard J.	Reg. No. 27,688
Riley, Louis A.	Reg. No. 39,817	Wisor, Rita M.	Reg. No. 41,382
Zahrt II, William D.	Reg. No. 26,070		

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Crawford PLLC.

Please direct all correspondence in this case to Crawford PLLC at the address indicated below:

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333 Washington Avenue North
Suite 5000
Minneapolis, MN 55401

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2	**Full Name Of Inventor**	**Family Name** Raeder	**First Given Name** Chris	**Second Given Name**
0	**Residence & Citizenship**	**City**	**State or Foreign Country**	**Country of Citizenship** USA
3	**Post Office Address**	**Post Office Address**	**City**	**State & Zip Code/Country**
Signature of Inventor 203:			**Date:**	

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.